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Assessment for Distribution Network Planning Schemes of Urban Electric Power System

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Abstract

As one important part of urban planning, distribution network planning is necessary to be comprehensively assessed to improve decision-making level and investment benefit. Some factors, such as anti-disaster ability and regional feature, have not been considered in existing researches. Considering these two factors, a novel comprehensive assessment method is proposed in this paper. Firstly, combining existing researches, anti-disaster ability is introduced in the index system which includes security, reliability, economy, flexibility, cooperativeness and anti-disaster ability; Secondly, based on analytic hierarchy process, the impacts of regional economy, disaster distribution and geography on the weights of each index are analyzed, proposing a comprehensive assessment method considering regional features; Finally, a twelfth five-year planning scheme in a city is taken as a case to analyze the practicability and effectiveness.

Keywords: distribution network planning, comprehensive assessment, regional characteristics, anti-disaster index

1. Introduction

Scientific and reasonable distribution network planning is the foundation and basic of grid construction and upgrading, which is also an important premise that power grid operates safely and reliably. It will improve the investment decision and benefits to comprehensively assess distribution network planning schemes and propose constructive amendment opinions according to the evaluation results.

Recently, integrated assessment of distribution network planning has been widely researched. An integrated assessment infrastructure was constructed in paper [1] and [2], whose assessment results were compared to existing network to measure the efficiency of planning. Based on economy concept, a comprehensive assessment method was proposed in [3], taking land and energy consumption and

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construction as an index, and optimizing capital flows and resource depletion from the view of input and output. With the deepening of planning work, however, we found that there are two general aspects with the current comprehensive assessment methods: one is that anti-disaster ability has not yet been taken as an index. While the frequent natural disasters raised great concern in grid anti-disaster ability, as a result of “Power Network Differential Planning Design guidance” being compiled by State Grid Corporation, proposing a differential planning thinking of “generally improved, strengthen in key regions” [4, 5], aiming at strengthening the anti-disaster ability of power network; The other one is, because of differences in economy, geography, land features and natural disasters, different regions have their own characteristics, whose emphasis in distribution network planning are correspondingly different. For this reason, different regions ask for different weight of each assessment index.

These two factors are considered in this paper, proposing a novel comprehensive assessment method. Firstly, anti-disaster ability is included in index infrastructure; secondly, the assessment method, based on analytic hierarchy process, considers the impact of regional feature on the weight of each index; finally, a distribution network twelfth five-year planning scheme is taken as a case to prove the novel method.

2. Integrated Assessment Methods of Distribution Network Planning

2.1 Analytic Hierarchy Process

Through Analytic Hierarchy Process (AHP), the related elements of decision-making will be broken into objectives, guidelines, schemes and other levels, based on the above hierarchy, taking a series of qualitative and quantitative analysis. Since the method has been extensively used in power system, this article only introduced planning of evaluation and its estimation processes briefly.

2.2 Evaluation Normalization

According to the specific circumstances of indexes, indicators of second level can be divided into three categories: cost-based indexes (index values as small as better), efficiency-based indexes (index values as big as better) and fixed index (the closer index values of a certain figure, the better). Reference to the method of finding a closer degree [13], which can use formula (1) for processing:

$$r_{ij}^* = \begin{cases} \frac{r_{ij}}{\max(r_{1j}, \dots, r_{mj})}, r_{ij} & \text{efficiency-based indexes} \\ \frac{\min(r_{1j}, \dots, r_{mj})}{r_{ij}}, r_{ij} & \text{cost-based indexes} \\ \frac{r_{ij}}{r_j}, r_{ij} < r_j, r_{ij} & \text{fixed index} \\ \frac{r_j}{r_{ij}}, r_{ij} > r_j, r_{ij} & \text{fixed index} \end{cases} \quad (1)$$

In the formula, r_{ij} is the j-th index value in program i, r_{ij}^* is the value after treatment; m is the number of planning program; r_j is the ideal values of j-th index.

2.3 Integrated Assessment Processing

AHP will be applied in a comprehensive assessment program whose steps are as follow:

- (1) According to the principles of urban network planning, and based on load forecast and regional characteristics, design different distribution network planning.
- (2) Compute various indexes in the second level for each planning, dealing with various indexes.
- (3) Using the AHP to solve the weight of various indexes, and get the weight vector of indexes:

$$\bar{W} = \alpha^h \quad (2)$$

In the formula, α is the weight value; h is the number of levels, in paper, h is 3.

- (4) The integrated evaluation value of the calculate program is S. The program having largest value of S is the optimal solution. The comprehensive evaluation value of i-th program is as flowing:

$$S_i = \sum_{j=1}^n r_{ij}^* \alpha_{ij} \quad (3)$$

In the formula, α_{ij} is the weight value of j-th index in program i.

3. The weight adjustment method considering the regional characteristics

3.1 The affecting factors of regional characteristics to the distribution network planning

- (1) The influence of the economic development

Economic development has made remarkable achievements in China, and average annual growth rate of GDP is 8-9%. However, economic level in three zones had large differences, level in eastern is higher than that in center which is higher than that in western.

The per capita GDP value higher regions are more developed, the distribution of load is concentrated relatively. In addition, the requirements for grid construction are different. The development of network should have certain in advance relative to economic development, the weight of the grid adaptation indicators can be appropriate to increase in the overall assessment.

- (2) The influence of the natural disaster distribution

The distribution of natural disasters can be divided into different characteristics of the three regions:

Coastal disaster region: more kinds of natural disasters, absolute loss serious, relatively less loss.

Central disaster region: natural disaster sort is more serious, absolute loss is more serious.

Western disaster region: sudden natural disasters species is less, environmental type natural disasters is especially serious, population and economic loss is lighter, resource destruction serious.

- (3) The influence of the physiognomy and river

Our country is vast. One mountain accounts for 33% of the national region. In addition, in our country runoff is very rich, but the space distribution is unbalanced. Mountains and rivers have large effects on grid construction.

3.2 The relevancy of the regional characteristics factors and the evaluation index

Different regional features led to the differences of related indexes. The relativity between regional characteristics factors and index weigh is showed as figure 2.

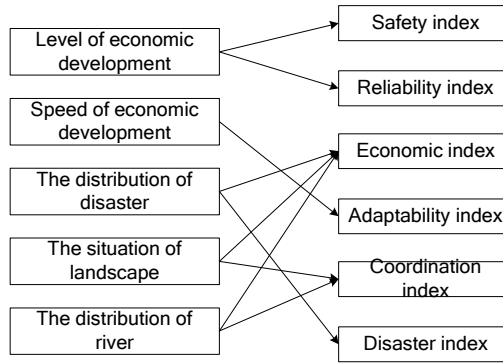


Fig.2 Relativity between regional characteristics factors and index weigh

3.3 The formation of the regional feature matrix

The regional feature matrix $B = (b_{ij})$ is the expression of the influence index weights by regional characteristics, b_{ij} is weight correction factor:

$b_{ij} = 1$ represents the i -th factor has no effect to the j -th evaluation index weight;

$b_{ij} > 1$ represents we need to improve the standard of the j -th evaluation index weight;

$b_{ij} < 1$ represents we need to reduce the standard of the j -th evaluation index weight.

3.4 Weight Adjustment

Appropriate improvements should be made for the assessment methods. Based on the regional characteristics matrix, we can obtain the objective weight vector $\omega' = \omega'^h$:

$$\omega'_j = \begin{cases} \max \{b_{1j}, b_{2j} \cdots b_{nj}\}, & \text{when } b_{1j}, b_{2j} \cdots b_{nj} \geq 1 \\ \min \{b_{1j}, b_{2j} \cdots b_{nj}\}, & \text{when } b_{1j}, b_{2j} \cdots b_{nj} \leq 1 \end{cases} \quad (4)$$

Combine the subjective weight and the objective weight into a comprehensive weight:

$$\theta'_{ij} = \frac{\alpha_{ij} \omega'_{ij}}{\sum_{j=1}^n \alpha_{ij} \omega'_{ij}} \quad (5)$$

The integrated assessment value of program i is calculated by the equation (6), the process of a comprehensive assessment is shown in Figure 3.

$$S'_i = \sum_{j=1}^n r_{ij} * \theta'_{ij} \quad (6)$$

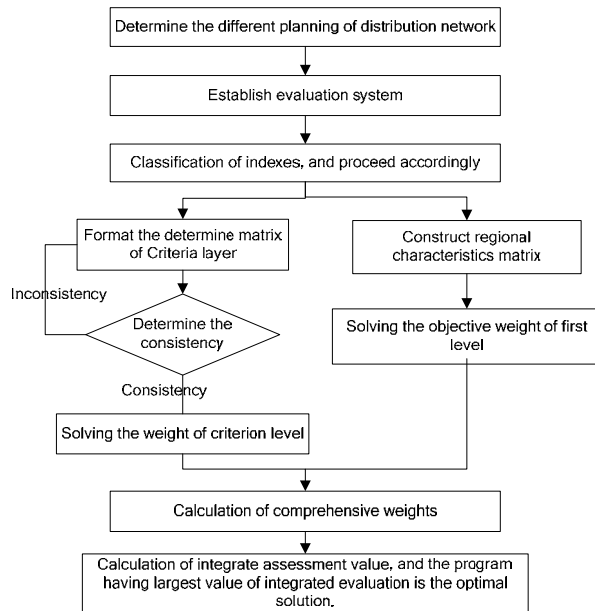


Fig. 3 Comprehensive assessment flow chart considering regional preferences.

4. Case Study

The “twelfth five-year” planning scheme in Zhejiang province is selected as a case. Based on load forecast results, the maximum load of A region is 1304 MW by 2015. We can design three schemes:

3220kV and 7110kV substations are going to be constructed according to Plan one, while in Plan two and Plan three, 4220kV and 8110kV substations, 4220kV substations and 10 110kV substations will be added respectively. By the end of 2015, the number of 10kV power lines will be 327, 366 and 414 respectively. The total capacity may achieve 2740MVA, 2990MVA, 3295MVA in three plans.

The calculation result of evaluation index value for three planning schemes is shown in Table 1.

Tab.1 Disposed result of distribution network planning evaluation index value

Types of indicators	A. power supply security			B. power supply reliability				C. economy		
	A1	A2	A3	B1	B2	B3	B4	C1	C2	C3
Plan one	0.964	0.959	0.872	0.850	1.000	0.908	0.919	1.000	1.000	0.771
Plan two	0.982	0.992	0.915	0.890	1.000	0.932	0.937	0.893	0.893	0.864
Plan three	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.751	0.751	1.000

Types of indicators	D. adaptability			E. coordination		F. anti-disaster ability			
	D1	D2	D3	E1		F1	F2	F3	F4
Plan one	0.779	0.775	0.858	0.762		1.000	0.967	0.797	0.894
Plan two	0.853	0.916	0.925	0.851		1.000	0.892	0.856	0.858
Plan three	1.000	1.000	1.000	1.000		1.000	1.000	1.000	0.948

A region stands in the south of Qiantang River. It's an important strategic region: economic growth rate remains at 15%, and the annual value of per capita GDP stays 8,700 yuan. The direct economic losses turn out to be much more than 50,000 yuan. The regional characteristics matrix of a region is as shown in Table 2.

Tab.2 Regional characteristics matrix

Factors	Security	Reliability	Economy	Adaptability	Coordination	Anti-disaster ability
Economic development level	1.3	1.3	1	1	1	1
Economic development rate	1	1	1	1.2	1	1
Disaster distribution	1	1	0.6	1	1	1.4
Type of landscape	1	1	0.7	1	0.7	1
River distribution	1	1	0.75	1	0.75	1

AHP weight and comprehensive weight are calculated and displayed in Table 3.

Tab.3 Comprehensive weight considering regional preference

Assessment value of indicator	Security	Reliability	Economy	Adaptability	Coordination	anti-disaster ability
AHP weight	0.115	0.324	0.324	0.061	0.061	0.115
Objective weight	1.300	1.300	0.600	1.200	0.700	1.400
Comprehensive weight	0.143	0.404	0.187	0.070	0.041	0.154

According to equation (6), the assess value of comprehensive weight for 3 plans is obtained respectively, when taking into account the characteristics of local region. Figure 4 shows the contrastive assessment results between proposal with considering the regional characteristics and not.

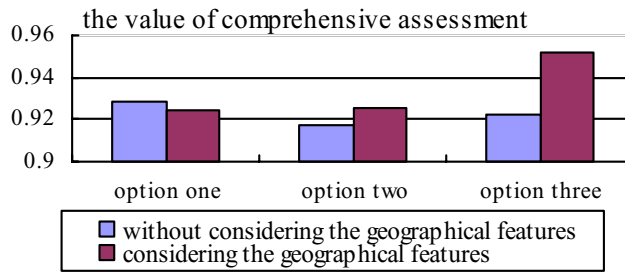


Fig. 4 Comparison of the assessment results

Table 3 shows that three weights significant changes. For economic indicator, the weight decreased from 0.324 to 0.187, a decrease of 0.137; meanwhile, the weight increased from 0.324 to 0.404, an increase of 0.08, increased from 0.115 to 0.154, an increase of 0.039. The rest three weights have changed little. The results of C1 and C2 in Plan three seem the worst. Due to the significant changes in weight of three indicators, the disadvantage of economic indicator in Plan three was neglect. Therefore, the value of Plan three exceeds the value of Plan one, and deserves the optimal planning solution. Based on the assessment result, we recommend Plan three as the final planning solution of the "twelfth five-year" power distribution network plan of A region.

5. Conclusions

- (1) Add an index related to anti-disaster ability, improving the index system of network assessment;
- (2) From five aspects, economy level, economy development speed, disaster distribution, landform and river distribution, the impacts on index weights are analyzed;
- (3) The results of case show that, the proposed method, which reasonably reflects the impact of regional features on planning, has certain practical value.

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